RESPIRATORY CARE Paper in Press. Published on March 23, 2021 as DOI: 10.4187/respcare.08328

Effect of Local Anesthesia on Pain During Arterial Puncture: The GAEL Randomized Placebo-Controlled Trial

Marc Beaumont, Marion Goret, Charles Orione, Alexandre Fauche, Emmanel Nowak, Angelina Dion, Veronique Darnois, Cecile Tromeur, Virginie Cogulet, Christophe Leroyer, Francis Couturaud, and Raphael Le Mao

BACKGROUND: Arterial puncture is often painful for patients. The aim of this study was to compare use of local anesthesia as a eutectic mixture of 2 local anesthetics, lidocaine and prilocaine, versus placebo. METHODS: We conducted a double-blind, randomized controlled trial. Subjects were eligible if arterial puncture was indicated. The primary outcome was an experienced pain > 2 on a numerical pain rating scale. As having had a previous experience of arterial puncture was expected to be predictive of the current response, we planned 3 comparisons between use of local anesthesia and placebo: in the whole sample, among subjects with a painful previous experience, and among subjects with a painless previous experience. Multiple testing was analyzed using the Bonferroni correction for the primary outcome. The secondary outcome was the numerical pain rating scale score itself. All analyses were performed on an intention-to-treat basis. RESULTS: A total of 136 subjects were included in this study. The primary outcome occurred in 20.9% in the active arm versus 37.7% in the placebo arm in the whole sample (relative risk 0.55; 95% CI when adjusting for multiple testing ranged was 0.28–1.09, *P* = .10; 95% CI without adjustment was 0.32–0.97, *P* = .038). No significant heterogeneity in the study treatment effect was found when considering previous painful or painless arterial puncture (*P* = .70). The numerical pain rating scale score was 1.55 ± 2.03 in active group versus 2.09 ± 2.15 in the placebo group (*P* = .13). CONCLUSION: We found that application of a eutectic mixture reduced the number of painful arterial punctures by 50% compared with placebo. However, this result is not statistically significant. (ClinicalTrials.gov registration NCT01964248.) *Key words: pain; arterial puncture; blood gas analysis; local anesthesia; lidocaine/prilocaine cream; nurses.* [Respir Care 0;0(0):1–●. © 0 Daedalus Enterprises]

Introduction

Arterial blood gas (ABG) testing is used to analyze patients' hematosis and acid/base state. Arterial puncture for ABG is often challenging for nursing staff and painful for patients. However, few providers use local anesthesia during arterial puncture.[1,2]

An observational study was carried out in our unit from 2006 to 2010 to evaluate the pain intensity of arterial puncture for ABG and to determine pain predictors. According to this study, no criterion seemed to predict pain, and pain intensity was highly variable between subjects.

Topical anesthetics reversibly block nerve conduction near the site of administration by targeting free nerve endings

Dr Beaumont is affiliated with the Pulmonary Rehabilitation Unit, Morlaix Hospital Centre, EA3878 (GETBO) CIC INSERM 1412, European University of Occidental Brittany, Morlaix, France. Ms Goret, Ms Darnois, and Drs Orione, Fauche, Tromeur, Leroyer, Couturaud, and Le Mao are affiliated with Department of Internal Medicine and Chest Diseases, EA3878 (GETBO) CIC INSERM 1412, University Hospital of Brest, European University of Occidental Brittany, Brest, France. Drs Nowak and Dion are affiliated with CIC INSERM 1412, University Hospital of Brest, Brest, France. Dr Cogulet is affiliated with the Pharmacy Unit, University Hospital of Brest, Brest, France.

The authors have disclosed no conflicts of interest.

Correspondence: Marc Beaumont PT PhD, EA 3878 (GETBO), CIC INSERM 1412, Pulmonary Rehabilitation Unit, Morlaix Hospital Centre, 29600 Morlaix, France. E-mail: mbeaumont@ch-morlaix.fr.

DOI: 10.4187/respcare.08328

RESPIRATORY CARE Paper in Press. Published on March 23, 2021 as DOI: 10.4187/respcare.08328

in the dermis or mucosa, thereby producing temporary loss of sensation in a limited area. To prevent patient pain, anesthetics could be administrated topically or through infiltration. However, injections of local anesthetics are painful[3,4] and can worsen needle anxiety or cause tissue edema.[5]

Different types of anesthetics and routes of administration have been evaluated with discordant results regarding effective pain relief.[6-12] France et al[3] compared the use of subcutaneous lidocaine and ethyl chloride versus no treatment on pain intensity during arterial puncture. Ethyl chloride was not found to reduce pain, and pain felt during lidocaine injection was similar to that of arterial puncture without anesthetic, suggesting a limited benefit of subcutaneous lidocaine.[3] In another study, vapocoolant spray (ethyl chloride) did not reduce pain during arterial puncture.[13] Bobbia et al[14] compared ultrasound-guided arterial puncture versus conventional sampling. The authors reported that ultrasonography increased the number and the duration of the procedure but had no effect on pain.[14] The gauge of the needle may be associated with the degree of pain during arterial puncture, but the results are controversial. Patout et al[15] compared pain experienced during arterial punctures performed with 23 French or 25 French needles, but the authors reported that the needle size had no significant impact on pain felt during arterial puncture.[15] Conversely, Ibrahim et al[16] compared the standard 23 French needle with an insulin needle and reported that arterial puncture using insulin needles was less painful than using standard needles.

A eutectic mixture of lidocaine and prilocaine, local anesthetics of the amide group, applied to diffuse into the stratum corneum, epidermis, and dermis to reach the superficial nerve endings, is commonly used for percutaneous anesthesia of healthy skin during blood sampling.[17] This anesthetic, topically administered, has the potential to decrease pain experienced during arterial puncture; however, the efficacy of this method has not been demonstrated yet.

Thus, we conducted a randomized controlled trial comparing local anesthesia with a eutectic mixture of 2 local anesthetics, lidocaine and prilocaine, versus placebo. The primary objective was to demonstrate that local anesthesia with a eutectic mixture of lidocaine and prilocaine applied before arterial puncture for ABG allows a greater reduction of frequency of painful arterial puncture compared to placebo. The secondary objectives were to compare the pain felt by subjects between both groups and in subgroup analyses (ie, subjects with unpleasant or painful memories of prior arterial puncture for ABG versus subjects without such memories).

QUICK LOOK

Current knowledge

Arterial puncture is felt painful by subjects. Application of Eutectic mixture of lidocaine and prilocaine is commonly used for percutaneous anesthesia of healthy skin during sampling blood, without evidence-based medicine.

What this paper contributes to our knowledge

Application of Eutectic mixture of lidocaine and prilocaine allowed to divide by 2 the number of painful Arterial Puncture in comparison with placebo, without significant difference between groups. Our results provide important evidence-based medicine response to this question about the interest of local anesthesia for pain reduction during arterial punctures.

Methods

Study population and ethic review

Between December 12, 2012, and October 2, Study population and ethic review 2015, patients hospitalized in or referred to the Pneumology Department were eligible if they required arterial puncture for ABG. Patients were not included if they met any of the following criteria: age < 18 y, inability to report a pain score, unfeasible radial arterial sampling, patients with pain > 0 on a numerical pain rating scale before the arterial puncture, known hypersensitivity to amide-bonded group local anesthetics or to any other component of the lidocaine/prilocaine cream, known porphyria, pregnancy, or the absence of written informed consent.

This single-center, double-blind (subjects, caregivers, investigators, and outcome assessors), parallel-group, randomized clinical trial was approved by the ethics board (CPP Ouest 6, n°2012-000489-39) in February 2012. Written informed consent was obtained from all subjects before randomization by physician investigators.

Randomization, Masking, and Interventions

At the time of inclusion, subjects were randomized via a computer-generated blind-fashion assignment sequence to receive either prilocaine/lidocaine cream (ie, the anesthetic group) or the placebo cream (ie, the placebo group). Nurses in the respiratory care unit administered all study treatments and performed all of the arterial punctures.

The active treatment evaluated was a lidocaine/prilocaine 5% cream marketed by Aguettant Laboratories (Lyon, France). The placebo, chosen for its identical texture, color, and smell to preserve blinding, was Excipial Hydrocreme (Spirig Pharma, Egerkingen, Switzerland). The tested treatment was prepared and blinded by the hospital pharmacy in identical single-dose tubes of 2 g. To obtain an anesthetic effect of at least 5 min, the cream was applied 2 h before the puncture at a radial artery perception site. The amount of cream to be applied was defined by the single-dose tube. The dose of cream was then covered with a transparent adhesive

RESPIRATORY CARE Paper in Press. Published on March 23, 2021 as DOI: 10.4187/respcare.08328

film. Other local treatments applied at the arterial puncture site were not allowed to avoid any risk of interactions with the evaluated treatments. Arterial puncture for ABG was performed using standardized 23 French needles in both groups.

Endpoints

The primary end point was an experienced pain > 2 (yes/no) on a numerical pain rating scale from 0 to 10. Pain intensity was measured on a numerical pain scale immediately before and just after the arterial puncture. The scale chosen was recommended by the institution's Pain Control Committee. No pain was represented as the 0 of the scale, with worst imaginable pain as the 10 of the scale. Because having had a previous experience of arterial puncture was expected to be predictive of the current response, we planned 3 comparisons between local anesthesia and placebo groups: in the whole sample, among subjects with a painful previous experience, and among subjects with a painless previous experience.

Before the arterial puncture, previous arterial puncture and related feelings (ie, the nurse asked subjects if they had ever had a previous arterial puncture and, if yes, their sensation during this previous puncture) were recorded, as were subjects' apprehension, physical condition, sample cutaneous conditions of realization, and baseline characteristics. After the arterial puncture, procedural difficulty, success, and subjects' treatment tolerance were collected. The secondary end point was the numerical pain rating scale score itself from 0 to 10.

Sample Size

The trial was designed to establish the superiority of local anesthesia over placebo to reduce the frequency of painful arterial puncture. We hypothesized a reduction of this frequency from 30% (with placebo cream) to 5% (with lidocaine and prilocaine cream). Two subgroup analysis were planned prior to randomization; the first was for subjects with unpleasant or painful memories of previous arterial punctures (group 1), and the second was for subjects without unpleasant or painful memories of previous arterial punctures (group 2). To maintain the overall probability of type 1 error at $< 5\%$, each individual hypothesis (whole sample, group 1, and group 2) was performed at the nominal risk ($\alpha = 0.05/3$). For an overall α-error of 5% and a 90% power to detect the expected difference between the anesthetic and placebo groups in the whole sample, the required sample size was 136, anticipating a maximum withdrawal rate of 10%.

Statistical Analyses

Continuous variables were expressed as mean ± SD. Subject characteristics were compared between anesthetic/placebo groups using the Student t test or the Wilcoxon test when appropriate for quantitative data, and using the chi-square test or the Fisher exact test for qualitative data. Painful arterial punctures frequencies were compared between groups using a generalized linear model with binomial distribution and logarithmic link function. This allowed estimating relative risks with confidence intervals and testing the homogeneity of the relative risks across the 2 predefined subgroups thanks to an interaction term in the model. Adjusted P values for multiple comparisons concerning the primary outcome were calculated according to the Bonferroni method in which the P values are multiplied by the number of comparisons. Pain scores were compared between the anesthetic and placebo groups using the Student t test. No correction was used for secondary outcomes. The statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, North Carolina).

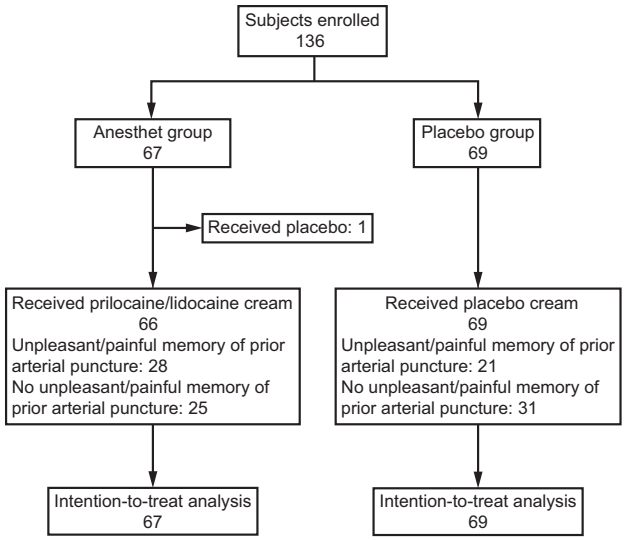

Figure 1. Flow chart.

Results

Subjects

Between December 2012 and October 2015, 136 subjects were included in the study and randomized to the anesthetic group ($n = 67$) or to the placebo group ($n = 69$) (Fig. 1). One subject received placebo cream instead of the evaluated treatment. Baseline characteristics of subjects are reported in Table 1. In the overall population, gender was mostly male (66.9%), mean body mass index was 29.18 ± 7.07 kg/m^2, most subjects were retired (71.6%), most currently or previously worked in a manual trade (71%), and most of the subjects had a previous arterial puncture, and had no apprehension about the procedure. The mean time between cream application and arterial puncture was 136.85 ± 22.31 min.

RESPIRATORY CARE Paper in Press. Published on March 23, 2021 as DOI: 10.4187/respcare.08328

Table 1. Baseline Subject Characteristics

Variables	Placebo Group	Anesthetic Group	*P*
Subjects, *n*	69	67	
Age, y	65 ± 12	64 ± 12	.32
Female	19 (28)	26 (39)	.16
Body mass index, kg/m^2	29.4 ± 6.9	29.0 ± 7.3	.73
Professional activity			.55
Retired	51 (74)	45 (70)	
Working	18 (26)	20 (31)	
Current or previous manual trade	47 (68)	50 (75)	.40
Permanent disability	10 (56)	6 (32)	.14
Previous arterial puncture	52 (75)	53 (79)	.60
Previous arterial puncture feeling			.17
Missing (ie, no previous arterial puncture)	17 (25)	14 (21)	
No memories	20 (38)	18 (34)	
Unpleasant	15 (29)	13 (25)	
Painful	6 (12)	15 (28)	
Not unpleasant memory	11 (21)	7 (13)	
Arterial puncture apprehension			.44
None	54 (78)	46 (69)	
Little	13 (19)	17 (25)	
A lot	2 (3)	4 (6)	
Radial artery perception			.35
Weak pulse	12 (17)	16 (24)	
Palpable pulse	57 (83)	51 (76)	
Skin condition			.09
Damaged skin	0 (0)	1 (1)	
Edema	1 (1)	0 (0)	
Hematoma	0 (0)	3 (4)	
Normal	68 (99)	63 (94)	
Time between cream deposit and puncture (minutes)	137.0 ± 23.5	136.7 ±21.2	.78
Success of arterial puncture on the first attempt			.91
Yes	57 (83)	55 (83.33)	
No	12 (17)	11 (17)	
During the first attempt, artery was found			.93
Missing data	1 (1)	2 (3)	
Not found	1 (1)	1 (2)	
Immediately	33 (49)	33 (51)	
After change of position of the needle	34 (50)	31 (48)	

Data are presented as *n* (%) or mean ± SD.

Primary and Secondary Outcomes

Arterial puncture was reported as painful by 37.7% of subjects (26 of 69) in the placebo group and by 20.9% of subjects (14 of 67) in the anesthetic group with a nonsignificant between-group difference (relative risk 0.55 [95% CI 0.28–1.09], $P = .10$ using Bonferroni correction). The subgroup analysis (ie, subjects with unpleasant or painful memory for prior arterial puncture [group1] and subjects without unpleasant or painful memory for prior arterial puncture [group 2]) did not show significant heterogeneity of the relative risks (group 1: 43% vs 18%; relative risk 0.42; group 2: 29% vs 16%; relative risk 0.55, *P* value for interaction = .70) (Table 2).

We found no significant difference for pain score between groups in the whole sample (2.09 vs 1.55, mean difference 0.54 [95% CI –0.17 to 1.25]) or in the subgroup analysis (Table 3). No significant between-group differences were observed for the overall incidence of adverse events.

Discussion

In this prospective, double-blind, randomized controlled trial, we found no significant difference in the reduction of the frequency of painful arterial puncture between

RESPIRATORY CARE Paper in Press. Published on March 23, 2021 as DOI: 10.4187/respcare.08328

Table 2. Between-Group Comparison of Painful Arterial Puncture Frequency

Arterial Puncture Experience	Placebo Group	Anesthetic Group	*P*, Unadjusted*	*P*, Adjusted†	Risk Ratio (98.33% CI)	*P*, Interaction
Whole sample			.032	.10	0.55 (0.28–1.09)	
Not painful	43 (62.32)	53 (79.10)				
Painful	26 (37.68)	14 (20.90)				
Subgroup analysis						
Group 1			.055	.17	0.42 (0.13–1.31)	.70
Not painful	12 (57.14)	23 (82.14)				
Painful	9 (42.86)	5 (17.86)				
Group 2			.25	.75	0.55 (0.15–1.99)	
Not painful	22 (7.97)	21 (84.00)				
Painful	9 (29.03)	4 (16.00)				

Data are presented as *n* (%). Group 1: Subjects with unpleasant or painful memory for prior arterial puncture. Group 2: Subjects without unpleasant or painful memory for prior arterial puncture.
* Unadjusted *P* value is significant if < .02.
† Bonferroni correction was used to perform adjusted *P* value (significant if < .05).

Table 3. Difference in Pain Score Between Groups

Pain Score	Placebo Group	Anesthetics Group	*P*	Difference in Means (95% CI)
Whole sample	2.09 ± 2.15	1.6 ± 2.03	.13	0.54 (–0.17 to 1.25)
Subgroup analysis				
Group 1	2.38 ± 2.25	1.5 ± 1.40	.11	0.91 (–0.14 to 1.96)
Group 2	1.65 ± 1.91	1.5 ± 2.43	.83	0.12 (–1.04 to 1.29)

Data are presented as mean ± SD. Group 1: Subjects with unpleasant or painful memory for prior arterial puncture. Group 2: Subjects without unpleasant or painful memory for prior arterial puncture.

groups (38% vs 21%, $P = .10$) or in the subgroup analysis (group 1: 43% vs 18%, $P = .17$; group 2: 29% vs 16%, $P = .75$).

To our knowledge, this is the first randomized, placebo-controlled trial that used the proportion of painful arterial punctures as the primary end point. Several reports used the decrease in pain intensity as a main end point to evaluate the effects of anesthetics.[6,7,10-12,18-20] However, if decreasing pain intensity of this procedure is a clinically relevant issue for patients, the benefit might be incomplete as some will still feel pain during the puncture. The use of our end point was more accurate as the objective of using anesthesia was to ensure that the puncture was not painful at all for subjects. However, our hypothesis of a reduction in painful arterial puncture frequency from 30% to 5% was overestimated. Moreover, we expected a decrease in painful arterial puncture rates by 83%. Despite these issues, we observed that application of a eutectic mixture of 2 local anesthetics (ie, lidocaine and prilocaine) reduced the number of painful arterial punctures by 50% compared to placebo, which is clinically important for patients. The use of the Bonferroni correction to analyze multiple comparisons led to nonsignificant results. A hierarchical testing strategy, testing the whole sample first with a significance level of $P < .05$, would have been more appropriate and perhaps successful. however, the sample size would be lower and we do not think this testing strategy could affects the results.

In subgroup analysis, the results were similar, although there is a lack of data for subjects with unpleasant or painful memory of previous arterial puncture and for subjects without unpleasant or painful memory, including subjects without arterial puncture experience prior to this study. Indeed, 23% of subjects did not have a prior arterial puncture, so they could not answer the question about their experience of a prior arterial puncture, which led to a smaller sample size and thus a loss of statistical power.

Consistent with other studies, the pain felt by subjects during the arterial puncture, as measured using numerical pain rating, was not significantly different between groups. Aaron et al[9] compared the effectiveness of topical tetracaine versus placebo gel prior to arterial puncture on pain measured with a visual analog scale. The authors concluded that tetracaine gel did not significantly decrease pain after arterial puncture in comparison with placebo gel.[9] Similarly, Tran et al,[7] in a randomized placebo-controlled trial, reported that the topical application of 4% amethocaine gel for 30 min was not effective in reducing the pain associated with arterial puncture compared to a placebo gel. In contrast, Youn et al[11] reported significant benefit of topical anesthesia (ie, a eutectic mixture of lidocaine and prilocaine) versus placebo on radial pain and sympathetic response during transradial coronary

RESPIRATORY CARE Paper in Press. Published on March 23, 2021 as DOI: 10.4187/respcare.08328

angiography. For the protocol, Youn et al[11] applied the anesthetic cream or placebo cream and, after 1–3 h, they injected lidocaine and then inserted the introducer sheath. Pain was compared between groups during lidocaine infiltration and during introducer sheath insertion. Youn et al[11] noted a significant difference showing decreased pain in the anesthetic group (using a visual analog pain scale) during lidocaine infiltration but not during introducer sheath insertion. A plausible explanation is that lidocaine infiltration is more superficial than introducer sheath insertion; thus, the anesthetic cream appears to be more effective for superficial insertion in comparison with deeper insertion.[11] This may explain the ineffectiveness of the anesthetic cream on pain during arterial puncture, which requires relatively deep insertion. Different authors have studied the effectiveness of lidocaine infiltration versus no infiltration on pain during arterial puncture, but the results are discordant.[6,18,19] Two reports compared the effectiveness of lidocaine infiltration versus lidocaine and prilocaine cream, but these results were also discordant.[12,20] In a randomized controlled trial, Haynes[10] reported that use of cryoanalgesia (ie, an ice bag) for 3 min prior to arterial puncture significantly decreased pain in comparison with no cryoanalgesia.

Our study has some limitations. First, using a hierarchical testing strategy to test the whole sample first with a significance level of $P = .05$ and then testing subgroups with statistical differences would have been more appropriate However, the sample size would have been smaller, and we do not think this testing strategy would affect the results. Second, our hypothesis of a reduction in painful arterial puncture frequency from 30% to 5% was overestimated. Lastly, nurses' experience and the length of time required for the puncture were not collected, which could be a confounding bias.

The strengths of our study are the use of a double-blind randomized design, a predefined and standardized protocol for local treatment application, and the use of predefined objective end points. Finally, to our knowledge, our study is the first randomized controlled trial to use the proportion of painful arterial puncture as the primary end point to evaluate the effects of local anesthetics.

Conclusions

We observed that application of a eutectic mixture of 2 local anesthetics, lidocaine and prilocaine, decreased the proportion of painful arterial punctures by 50% compared with placebo. However, this result is not statistically significant due to multiple testing and is a lower benefit than expected. We found no significant difference for pain scores between groups. Future studies should evaluate the best prevention of pain during arterial puncture to increase quality of care for this common procedure, which remains painful for many patients. Attention should also be given to identify predictive factors of painful arterial puncture to focus preventive efforts on the most sensitive patients.

REFERENCES

1. Sado DM, Deakin CD. Local anaesthesia for venous cannulation and arterial blood gas sampling: are doctors using it? J R Soc Med 2005;98(4):158-160.
2. Lightowler J, Elliott M. Local anaesthetic infiltration prior to arterial puncture for blood gas analysis: a survey of current practice and a randomised double blind placebo controlled trial. J R Coll Physicians Lond 1997;31(6):8-9.
3. France JE, Beech FJM, Jakeman N, Benger JR. Anaesthesia for arterial puncture in the emergency department: a randomized trial of subcutaneous lidocaine, ethyl chloride or nothing. Eur J Emerg Med 2008;15(4):218-220.
4. Matheson L, Stephenson M, Huber B. Reducing pain associated with arterial punctures for blood gas analysis. Pain Manag Nurs 2014;15(3):619-624.
5. Kumar M, Chawla R, Goyal M. Topical anesthesia. J Anaesthesiol Clin Pharmacol 2015;31(4):450-456.
6. Giner J, Casan P, Belda J, González M, Miralda RM, Sanchis J. Pain during arterial puncture. Chest 1996;110(6):1443-1445.
7. Tran NQ, Pretto JJ, Worsnop CJ. A randomized controlled trial of the effectiveness of topical amethocaine in reducing pain during arterial puncture. Chest 2002;122(4):1357-1360.
8. Ballesteros-Peña S, Fernández-Aedo I, Hoz GV, Diasure D. Eficacia del cloruro de etilo en aerosol como anestésico local previo a la punción arterial: ensayo clínico aleatorizado controlado con placebo. Emergencias 2017(29):161-166.
9. Aaron SD, Vandemheen KL, Naftel SA, Lewis MJ, Rodger MA. Topical tetracaine prior to arterial puncture: a randomized, placebo-controlled clinical trial. Respir Med 2003;97(11):1195-1199.
10. Haynes JM. Randomized controlled trial of cryoanalgesia (ice bag) to reduce pain associated with arterial puncture. Respir Care 2015;60(1):1-5.
11. Youn YJ, Kim W-T, Lee J-W, Ahn S-G, Ahn M-S, Kim J-Y, et al. Eutectic mixture of local anesthesia cream can reduce both the radial pain and sympathetic response during transradial coronary angiography. Korean Circ J 2011;41(12):726-732.
12. Latsios G, Toutouzas K, Antonopoulos AS, Melidi E, Synetos A, Vogiatzi G, et al. Anesthetic ointment only (lidocaine/prilocaine) instead of injectable local lidocaine in trans-radial catheterization: a viable no-needle alternative. J Interv Cardiol 2017;30(4):382-386.
13. Farahmand S, Mirfazaelian H, Sedaghat M, Arashpour A, Saeedi M, Bagheri-Hariri S. Vapocoolant spray effectiveness on arterial puncture pain: a randomized controlled clinical trial. Acta Med Iran 2017;55(2):87-91.
14. Bobbia X, Grandpierre RG, Claret PG, Moreau A, Pommet S, Bonnec JM, et al. Ultrasound guidance for radial arterial puncture: a randomized controlled trial. Am J Emerg Med 2013;31(5):810-815.
15. Patout M, Lamia B, Lhuillier E, Molano LC, Viacroze C, Benhamou D, et al. A randomized controlled trial on the effect of needle gauge on the pain and anxiety experienced during radial arterial puncture. PLoS One 2015;10(9):e0139432.
16. Ibrahim I, Yau YW, Ong L, Chan YH, Kuan WS. Arterial puncture using insulin needle is less painful than with standard needle: a randomized crossover study. Acad Emerg Med 2015;22(3):315-320.
17. Hudson TL, Dukes SF, Reilly K. Use of local anesthesia for arterial punctures. Am J Crit Care 2006;15(6):595-599.

RESPIRATORY CARE Paper in Press. Published on March 23, 2021 as DOI: 10.4187/respcare.08328

18. Wade RG, Crawfurd J, Wade D, Holland R. Radial artery blood gas sampling: a randomized controlled trial of lidocaine local anesthesia. J Evid Based Med 2015;8(4):185-191.
19. Hajiseyedjavady H, Saeedi M, Eslami V, Shahsavarinia K, Farahmand S. Less painful arterial blood gas sampling using jet injection of 2% lidocaine: a randomized controlled clinical trial. Am J Emerg Med 2012;30(7):1100-1104.
20. Joly L, Spaulding C, Weber S, Benhamou D, Ali OS. Topical Lidocaine-prilocaine cream (EMLA@) versus local infiltration anesthesia for radial artery cannulation. Anesth Analg 1998;87:403-406.